DESERT TORTOISE HABITAT USE AND HOME RANGE SIZE ON THE FLORENCE MILITARY RESERVATION: A PILOT STUDY

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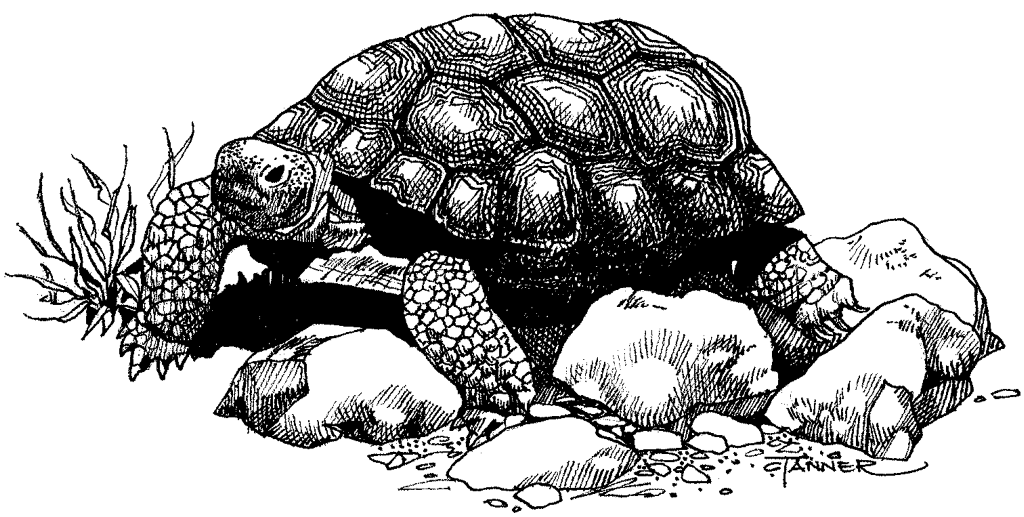

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DESERT TORTOISE HABITAT USE AND HOME RANGE SIZE ON THE FLORENCE MILITARY RESERVATION: A PILOT STUDY

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INTRODUCTION

The desert tortoise *Gopherus agassizii* has the broadest range of latitude and habitats of the four species of North American tortoises (Germano and others 1994). Throughout the Mojave Desert, tortoises occur on sandy loam to rocky soils on valley bottoms and bajadas and occasionally on rocky hillsides (Germano and others 1994). In both the Lower Colorado River Valley and Arizona Upland subdivisions of the Sonoran Desert, tortoises typically occur on rocky hillside slopes and bajadas and are absent from intermountain valley floors (Germano and others 1994). Tortoises in the Sonoran Desert may also be found in soil burrows and caliche caves of incised washes extending from the bajadas (Woodman and others 1999). Tortoises at the southern end of their distribution in Sinaloan thornscrub and Sinaloan deciduous forest have only been found on hillsides (Fritts and Jennings 1994; Germano and others 1994).

Tortoises use burrows extensively throughout their range (Germano and others 1994). Burrow depths reach 10 m in the northeastern Mojave Desert, which is subject to cold winter temperatures (Woodbury and Hardy 1948). Burrow depths at lower (warmer) elevations in the Mojave Desert usually range from 1 to 3 m (Luckenbach 1982). Burrow depths in the tortoise's Sonoran and Sinaloan distribution are also usually relatively shallow, except in washes, probably as a result of rocky substrates and mild winters (Germano and others 1994). Rocky substrates also limit the number of available burrow sites in the Sonoran Desert (Averill-Murray and others, *in press* a).

Tortoises use multiple burrows, often exceeding 20 in a year, within their home ranges (Averill-Murray and others, *in press* b). Annual home range areas are highly variable, with averages ranging from 9.2-25.8 ha for males and 2.6-23.3 ha for females in the Sonoran Desert (Averill-Murray and others, *in press* b). Environmental conditions play a role in this variability. In the Mojave Desert, tortoise home ranges were smaller in a drought year than in a wet year (Duda and others 1999).

A unique Sonoran Desert tortoise population occurs in the San Pedro Valley, Arizona. Tortoises occur mainly on steep canyon slopes at this site, but it differs from other Sonoran Desert populations in that it lacks large boulders (Woodman and others 1996). Most tortoise burrows at the San Pedro site occur in terrace gravel caves or diatomacious earth, rather than below rocks or boulders as in other populations (Woodman and others 1996). Two-year home range sizes were relatively small for tortoises in this population (mean = 11.0 and 2.6 ha for males and females, respectively), possibly due to the well-developed soils and dense vegetation at the site (Bailey 1992).

FLORENCE MILITARY RESERVATION

The Florence Military Reservation (FMR) is a 10,421-ha site in Pinal County, Arizona, approximately 80 km southeast of metropolitan Phoenix (Department of Emergency and Military Affairs [DEMA] 1997). FMR contains gently sloping to nearly flat alluvial fan slopes in the north and steep, rugged hills in most of the south; elevations range from about 450 to 610 m (DEMA 1997). Erosion of the mountains to the east has filled the alluvial valley with unconsolidated to weakly consolidated silts, sands, clays, and gravels; the hills consist of prominent volcanic outcrops (DEMA 1997). Vegetation at FMR contains components of the Lower Colorado River Valley and Arizona Upland subdivisions of the Sonoran Desert, with microphyll woodlands along many washes (Snetsinger and Spicer 2001; Fig. 1).

In August 1997, Arizona Army National Guard personnel conducted a desert tortoise survey at FMR. Thirty-four tortoises were located during the 1997 surveys, supplementing several previous records from 1993. All tortoises were located in or near washes (C. Pedersen, pers. comm., 1997; Fig. 1).

This report presents the results of a 1-year pilot study of desert tortoise habitat use relative to lands used for military training activities at FMR, particularly in Training Area B. Training Area B is located in the northern, mostly alluvial, portion of FMR and is used for training and artillery firing (DEMA 1997). This area contains 14 designated ground support training areas (firing boxes), each measuring about 500 x 1000 m; 6 of these firing boxes have been newly established but not yet opened (Fig. 1). Artillery units are authorized to maneuver their howitzers, vehicles, and troops off-road within these designated areas (DEMA 1997). The objective of this study was to collect baseline data on the spatial and temporal use of habitat at FMR relative to these firing boxes and roads.

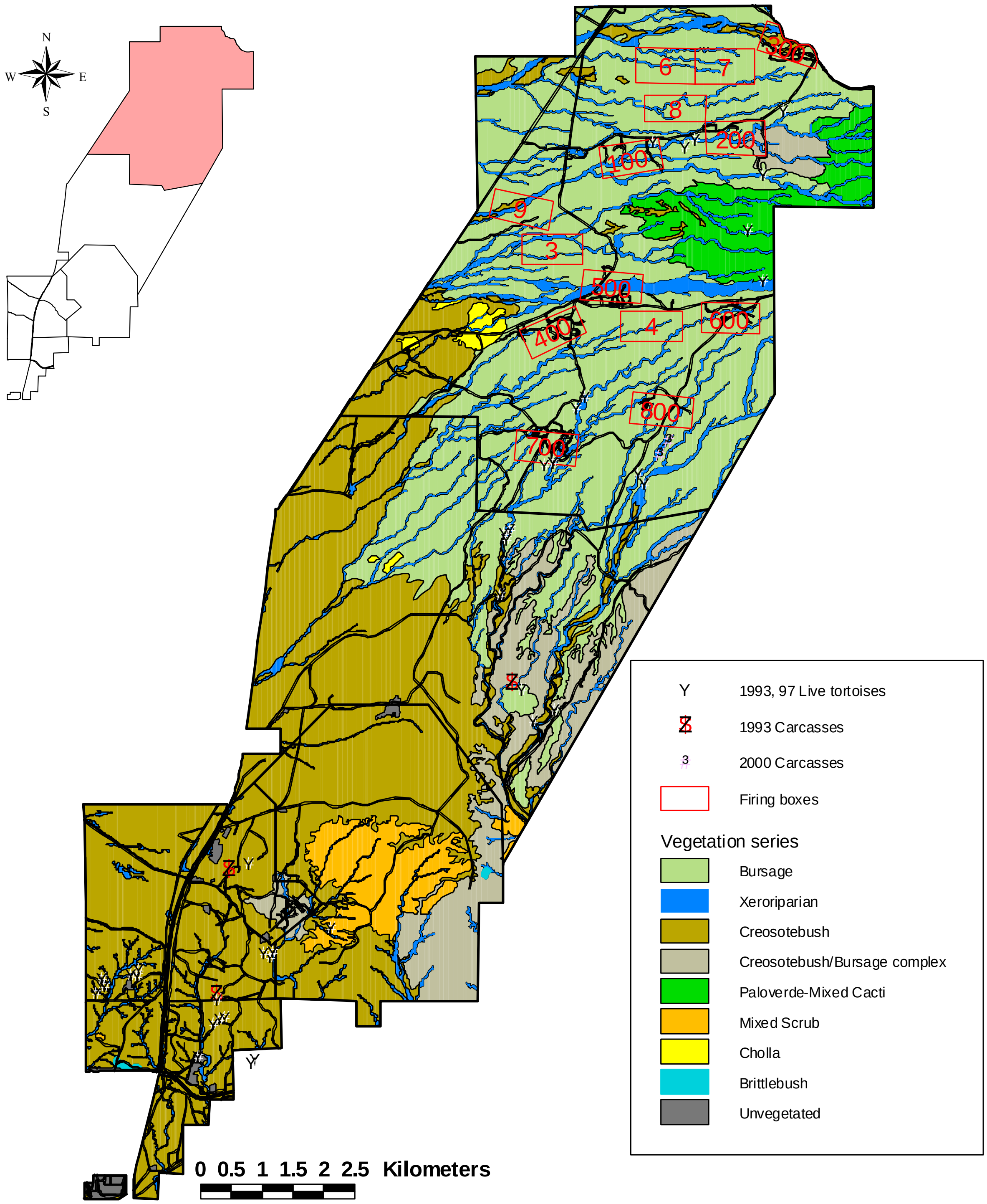

Figure 1. Map of Florence Military Reservation. Vegetation types to series level, firing boxes, approximate locations of live and dead tortoise observations from 1993 and 1997 surveys, and carcass locations from the current study are illustrated. Inset highlights Training Area B.

METHODS

Project personnel completed a total of 58 person-field days searching for and monitoring desert tortoises between 16 March and 14 November 2000. Volunteers contributed an additional 13 days for a total of 71 person-field days during the study. We searched all areas in which tortoises had previously been found in Training Area B (Fig. 1), and we spent additional time searching for incised washes containing caliche caves or other sites suitable for burrow excavation.

We recorded midline carapace length (MCL) to the nearest mm with pottery calipers and a metal rule. Each tortoise was assigned a number, and marginal scutes were permanently notched (with triangular files) based on a code adapted by Berry (1984; Appendix). Bridge marginals were not notched on tortoises <120 mm MCL. We also wrote the identification number on a dot of correction fluid painted on the right fourth costal scute and covered it with clear epoxy. We determined gender for tortoises ≥180 mm MCL; we considered those with concave plastrons to be males. We took close-up photographs of the full carapace, full plastron, and left fourth costal of each tortoise. We attached radio transmitters (AVM Instrument Company or Wildlife Materials) to the anterior carapace of adult tortoises using 5-minute gel epoxy (Devcon) and monitored telemetered tortoises each week. We visually inspected each tortoise for injuries, morphological anomalies, and symptoms of cutaneous dyskeratosis and upper respiratory tract disease (URTD). We handled all tortoises with disposable latex gloves to minimize the potential spread of pathogens between individual tortoises. Any instruments coming into contact with a tortoise during handling were disinfected prior to use on another tortoise (Averill-Murray 2000).

We recorded each tortoise's position with a global positioning system receiver (Basic+ or GeoExplorer II, Trimble Navigation Ltd.), post-processed the data for accuracy with Pathfinder Office (Trimble Navigation Ltd.), and mapped the locations with ArcView GIS 3.2 (Environmental Systems Research Institute, Inc.). Shortly following the removal of selective availability of satallite data on 1 May 2000, we recorded tortoise positions with Garmin GPS III Plus (Garmin Corporation) receivers and discontinued post-processing.

We marked burrows with individually numbered aluminum tags which we affixed with epoxy to rock faces above the burrow, wired to overhanging vegetation, or wired to a nail driven into caliche above the burrow entrance. We use the term 'burrow' to specifically refer to a subsurface cavity formed by erosion and/or excavated by a tortoise or another animal (Burge 1978), including cavities eroded or excavated into hard calcium carbonate (caliche) soils along incised arroyo (dry stream) banks. We only marked relatively permanent burrows, defined as modified shelters ≥1/2 the tortoise's shell length. We did not include pallets (shallow, scraped out areas <1/2 tortoise length) or other temporary shelters unmodified by the tortoise (for example, under trees, shrubs, or rocks).

We estimated minimum convex polygon (MCP) home ranges for tortoises with ≥4 observations with the Animal Movement extension to ArcView (Hooge and Eichenlaub 1997). Other home range studies have applied Jennrich and Turner's (1969) correction for sample size bias to MCP estimates (for example, Barrett 1990), but Rautenstrauch and Holt (1995) reported that this correction routinely overestimated home range size, sometimes as much as 200%. Because of this overestimation and the fact that our MCP estimates were uncorrelated with sample size, we chose not to apply Jennrich and Turner's correction factor. We overlayed tortoise locations and home range polygons on a draft vegetation map in ArcView (resolution to the series level of Brown and others 1979) prepared for FMR (Snetsinger and Spicer 2001). We then computed the area of each vegetation series within each home range polygon and computed the proportion of each tortoise's observed locations in each series.

RESULTS

We marked 13 tortoises on FMR in the year 2000: 6 adult males, 6 adult females, and 1 juvenile (Table 1; Figs. 2-5). Of these, 5 males and 5 females were fitted with radio transmitters. Male tortoise #407 was originally fitted with a transmitter, but he moved about 1200 m south of the nearest firing box (Fig. 5). His transmitter was removed when 2 new tortoises (#410 and #411) were found in closer proximity to the firing boxes (Figs. 2-3). Male tortoise #402 was lost after the third week of monitoring, either as a result of transmitter failure or a long-distance movement. We also found 2 tortoise carcasses in the southeast portion of Training Area B (Fig. 1).

Table 1. Desert tortoises marked on the Florence Military Reservation in the year 2000. Tortoises telemetered at the end of the year are indicated with an asterisk.

Tortoise #	Sex	MCL (mm)	Date Marked	# Locations
400*	M	204	23 Mar 00	31
401	U	64	4 Apr 00	1
402*	M	242	18 Apr 00	3
403*	M	277	25 Apr 00	21
404*	F	264	25 Apr 00	27
405*	F	232	24 May 00	24
406*	M	247	25 Jul 00	14
407	M	268	29 Aug 00	6
408*	F	229	5 Sep 00	7
409	F	238	26 Sep 00	3
410*	F	250	3 Oct 00	4
411*	M	240	3 Oct 00	4
502*	F	218	8 Aug 00	12

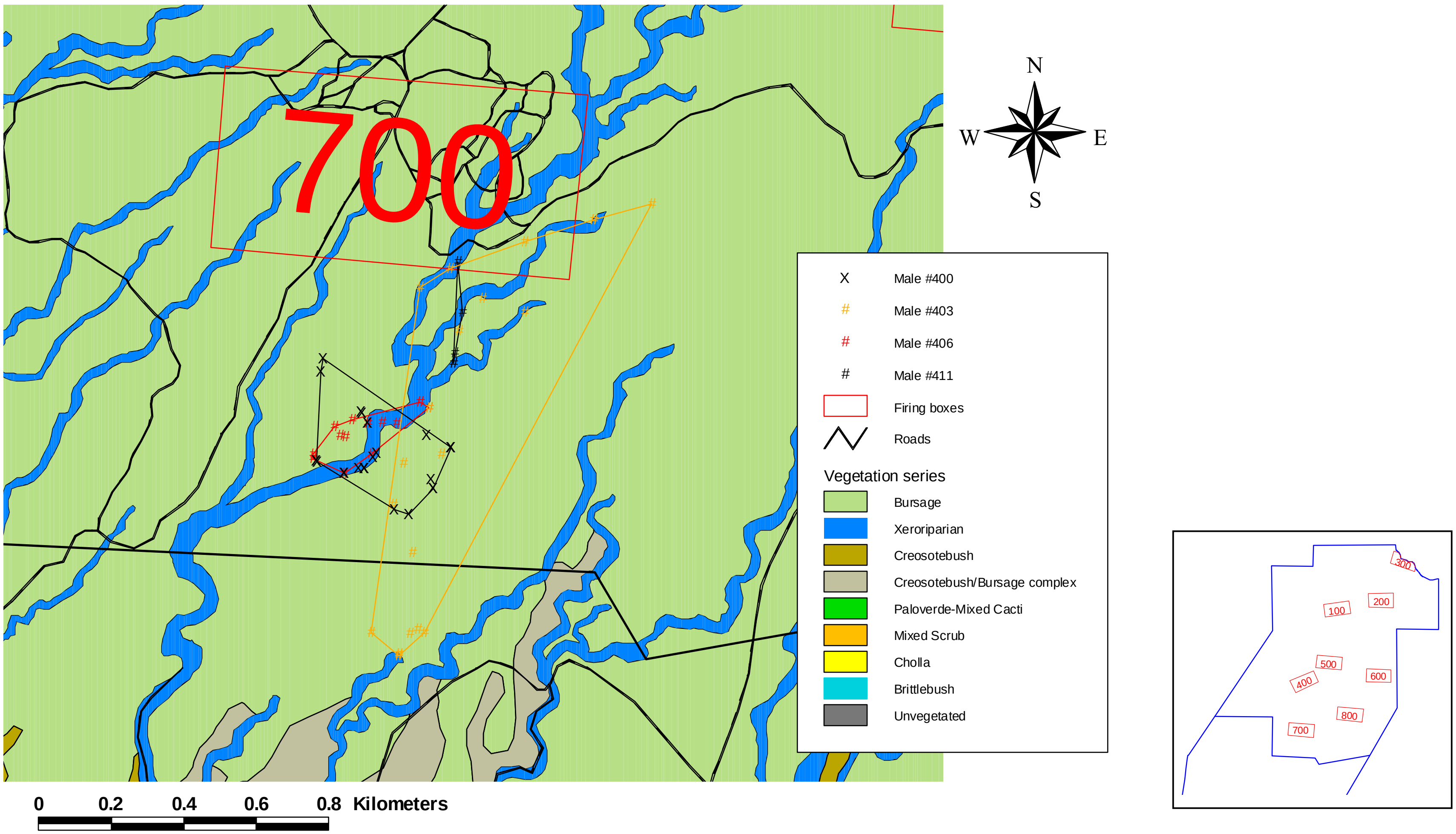

Figure 2. Locations and MCP home range polygons for telemetered male desert tortoises at the Florence Military Reservation, year 2000. Inset shows Training Area B.

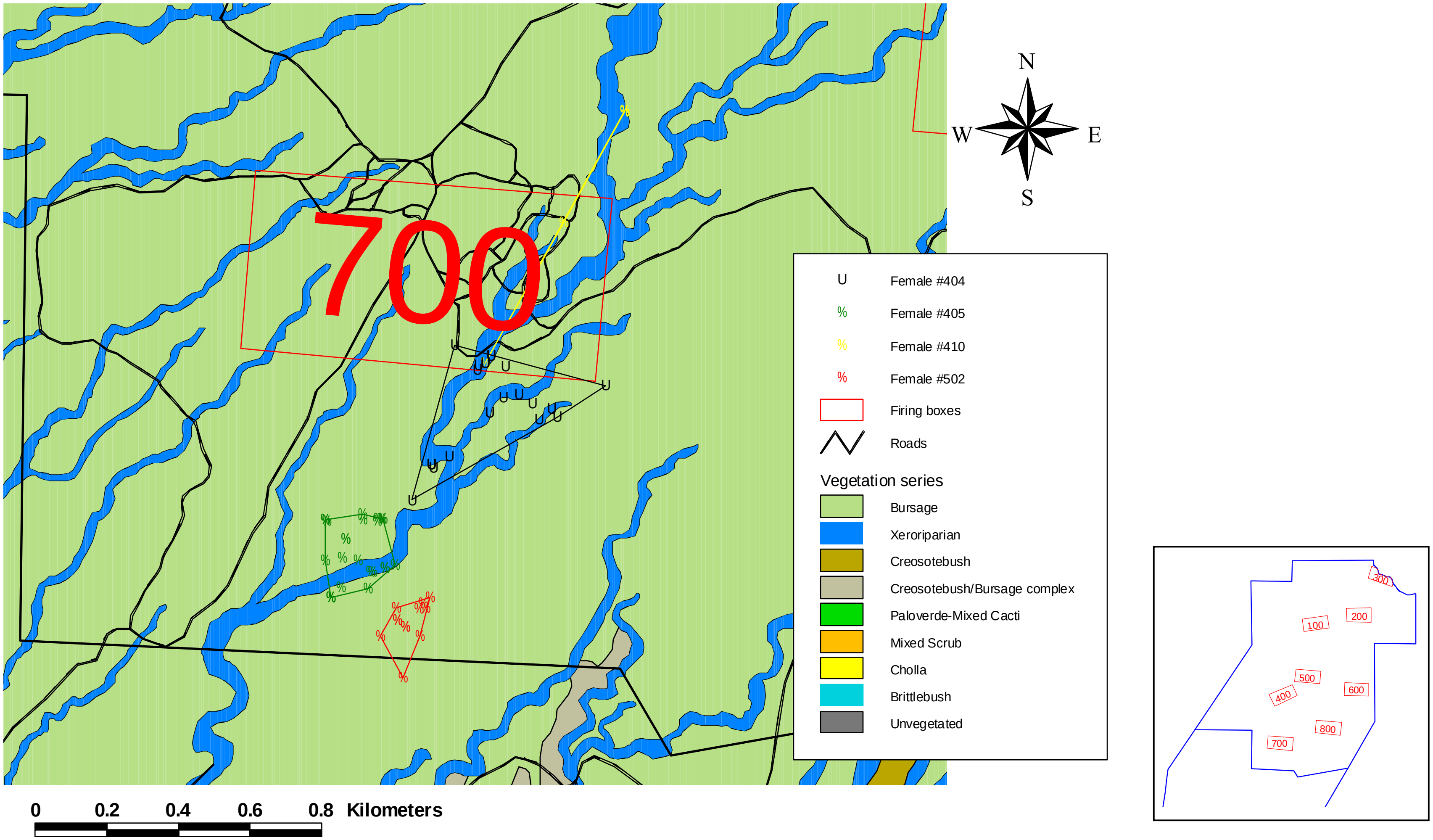

Figure 3. Locations and MCP home range polygons for telemetered female desert tortoises at the Florence Military Reservation, year 2000. Inset shows Training Area B.

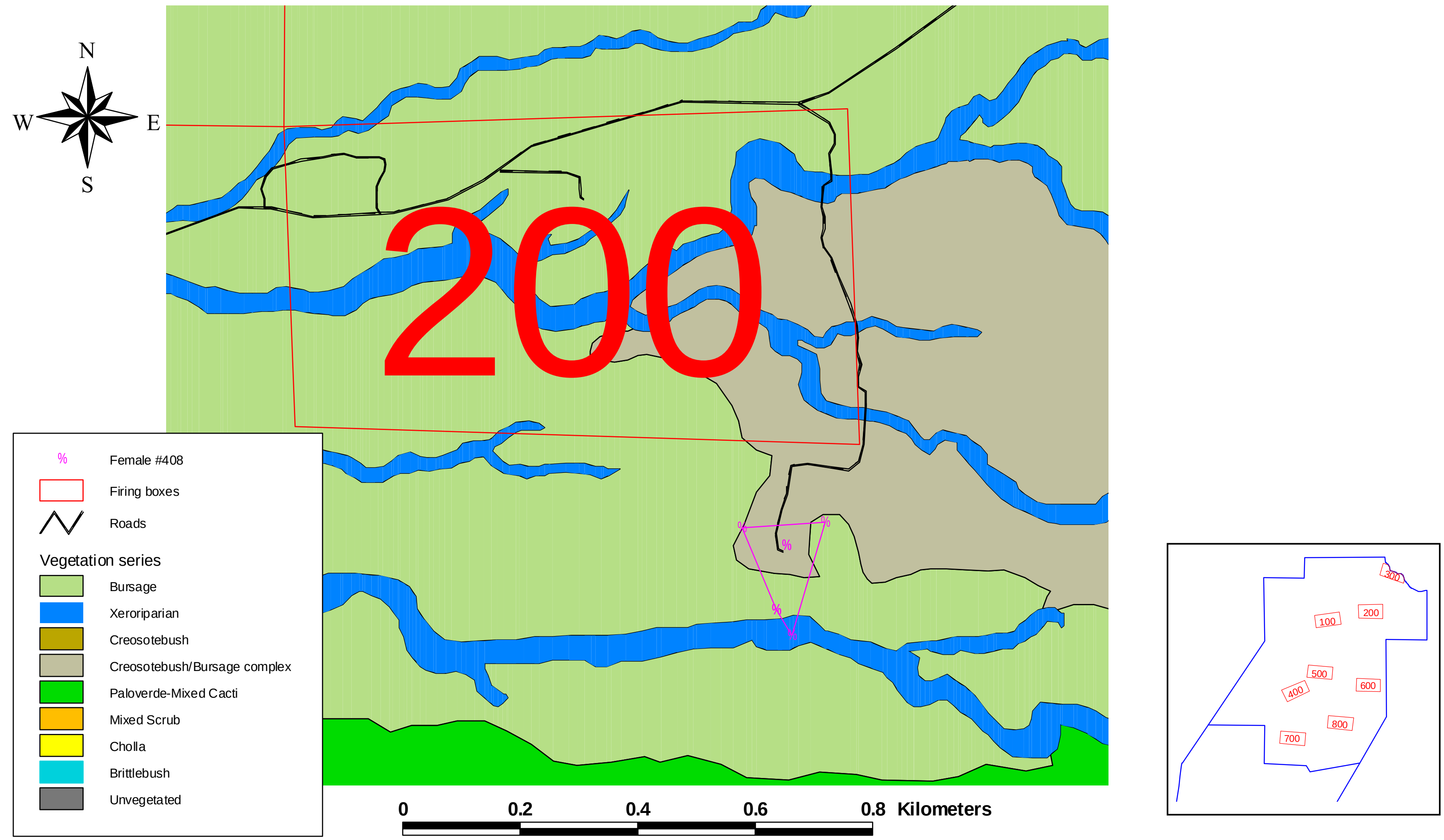

Figure 4. Locations and MCP home range polygon for telemetered female desert tortoise #408 on the Florence Military Reservation, year 2000. Inset shows Training Area B.

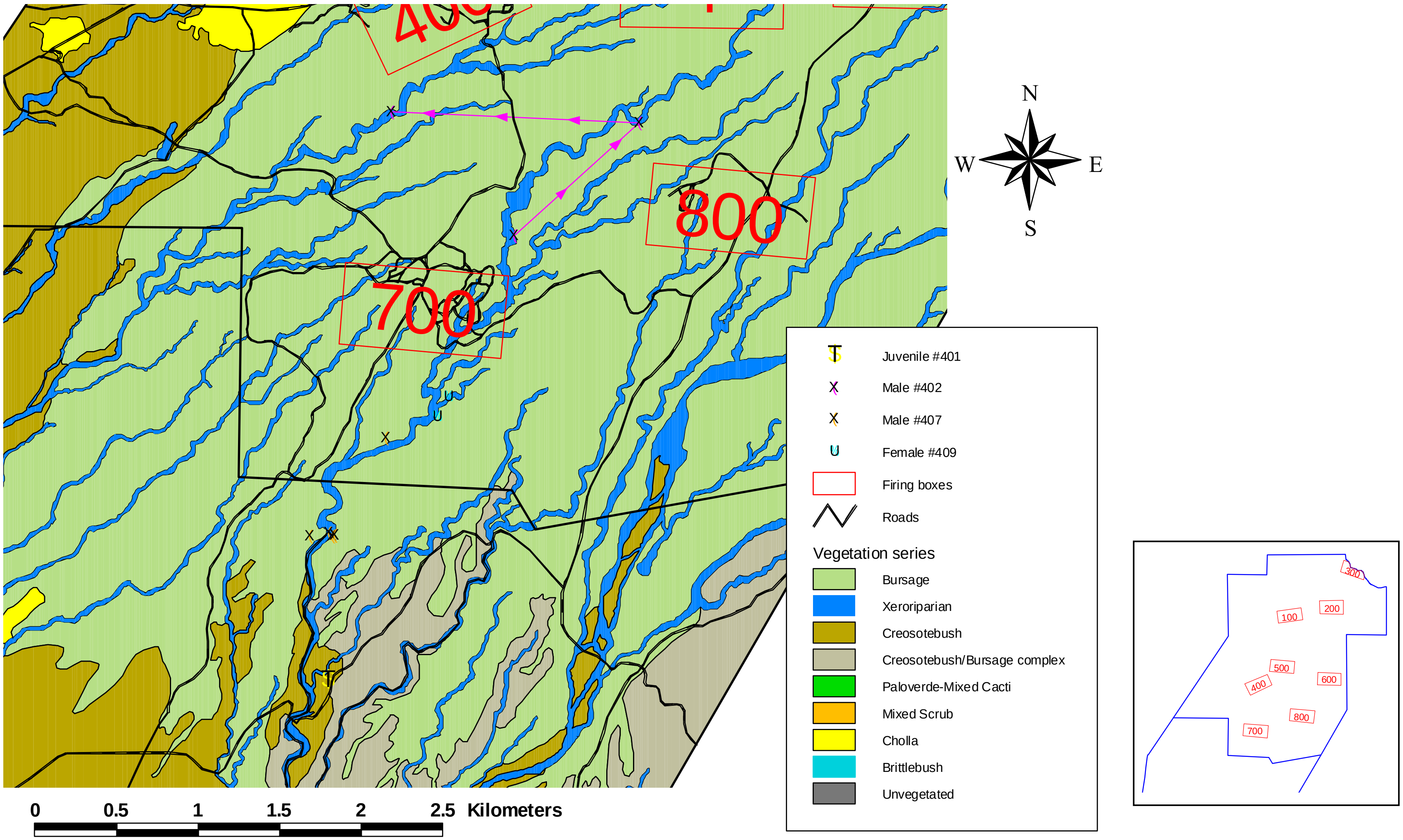

Figure 5. Locations of untelemetered desert tortoises on the Florence Military Reservation, year 2000. Inset shows Training Area B.

Few (1-3) tortoises were found within firing boxes during the 1993 and 1997 surveys, although several other observations were made within relatively close proximity to a firing box (Fig. 1). We only found tortoises within firing box #700, the southern-most box within Training Area B, during our surveys. Male #411's northern-most location (out of 4 total) was in a caliche cave (burrow #9, with females #404 and 410 also inside) next to a road on the southern edge of firing box #700 (Fig. 2). We found male #403 within or in close proximity to the southeast corner of firing box #700 on several occasions (Fig. 2). We also found females #404 and 410 within this firing box. We found female #404 several times along the east end of the southern edge of the firing box; female #410 moved from burrow #9 on her first location to a pallet in the northeast corner of the firing box, before continuing out of the firing box to the north (Fig. 3).

HOME RANGE AND HABITAT USE

We estimated tortoise home range sizes of up to 39 ha during the period of study (Table 2; Figs. 2-5). Tortoises spent nearly all their time in xeroriparian (riparian scrub/interior strand) areas and bursage-dominated habitat (Table 2; Figs. 2-5). Female #408 was the only telemetered tortoise that we found in the creosotebush or paloverde/mixed cacti series, with 1 observation in each series (Table 2; Fig. 4). Tortoise #401's lone oberservation also occurred in the creosote series (Table 2; Fig. 5). Male #403 and female #404 were the only tortoises whose home range polygons included the cholla series, but we never actually found male #403 in this series (Table 2; Fig. 2). Female #502 was found exclusively in the bursage series during the period of study (Table 2; Fig. 3).

Closer examination of those tortoises with >20 observations reveals some interesting patterns. Male #403 and female #405 appeared to use the xeroriparian areas much less than bursage habitat (Table 2; Figs. 2-3). The proportion of xeroriparian habitat included in both tortoises' home range polygons was <25% and corresponded well with the proportion of observations in that habitat type. Similarly, male #400's home range polygon contained only 14% xeroriparian habitat; however, we found this tortoise in the xeroriparian area a disproportionate 45% of the time (Table 2; Fig. 2). Female #404 appeared to use xeroriparian and bursage habitats in opposite proportion to their availability within her home range, with about 1/3 of her home range area containing xeroriparian habitat compared to 2/3 of our observations (Table 2; Fig. 3).

BURROWS

We marked 31 burrows at FMR. Of these, 24 were caliche caves and 7 were soil burrows often below live or dead vegetation. Most of the caliche cave shelters occurred within xeroriparian areas, with the remaining occurring in small arroyos in the bursage series (Table 3). Six of the soil burrows occurred within the bursage series, and the last was in the creosotebush series (Table 3).

Table 2. Minimum convex polygon (MCP) home range areas, including component habitat types, for desert tortoises at the Florence Military Reservation in the year 2000. Total habitat areas may differ from total MCP areas and proportions may not sum to 100% due to rounding.

Tort.		Total MCP		Xeroriparian		Bursage		Cholla		Creosote		Paloverde/mixed cacti	
#	Sex	ha	n	ha	n	ha	n	ha	n	ha	n	ha	n
400	M	8.85	31	1.24 14%	14 45%	7.61 86%	17 55%						
401	U	---	1							---	1		
402	M	---	3	---	3								
403	M	39.03	21	4.06 10%	4 19%	32.24 83%	17 81%	2.72 7%	0 0%				
404	F	9.97	27	3.06 31%	18 67%	6.86 69%	8 30%	0.05 <1%	1 4%				
405	F	3.51	24	0.77 22%	5 21%	2.75 78%	19 79%						
406	M	2.65	14	1.15 43%	7 50%	1.49 57%	7 50%						
407	M	4.23	6	1.19 28%	1 17%	3.05 72%	5 83%						
408	F	1.39	7	0.04 3%	1 14%	0.40 29%	4 57%			0.83 60%	1 14%	0.11 7%	1 14%
409	F	---	3	---	1	---	2						
410	F	0.10	4	0.03 30%	3 75%	0.07 70%	1 25%						
411	M	0.26	4	0.11 42%	3 75%	0.16 62%	1 25%						
502	F	1.66	11			1.66 100%	11 100%						

Table 3. Permanent burrows used by desert tortoises according to habitat at the Florence Military Reservation in the year 2000.

Shelter Type	n	Xeroriparian	Bursage	Creosotebush
Caliche cave	24	16 (67%)	8 (33%)	0
Soil burrow	7	0	6 (86%)	1 (14%)
Total	31	16 (52%)	14 (45%)	1 (3%)

We usually found tortoises in a permanent shelter, whether it was a caliche cave or another soil burrow. Individual tortoises used up to 7 different burrows during the study, and up to 100% of an individual's observations occurred in burrows (Table 4). Tortoises with >20 observations used 4-6 burrows for 29-61% of their observations (Table 4). We also made a total of 25 observations of tortoises in non-permanent shelters, mostly within bursage-dominated habitat. Twenty-two of these were pallets or unmodified shelters, and 13 were specifically associated with *Ambrosia deltoidea*. The remaining 3 observations were instances in which the tortoise burrowed into a packrat *Neotoma albigula* nest in the bursage vegetation series.

Table 4. Burrow use by desert tortoises at the Florence Military Reservation in the year 2000. n = total # different burrows used by each tortoise; obs. = # observations in burrows for each tortoise. Tortoises with >20 total observations are indicated with an asterisk.

		Total # Burrows		Xeroriparian		Bursage		Creosotebush	
Tortoise #	Sex	n	obs.[A]	n	obs.[B]	n	obs.[B]	n	obs.[B]
400*	M	6	19 (61%)	4 (67%)	12 (63%)	2 (33%)	7 (37%)		
401	U	1[C]	1					1	1
402	M	1	1 (33%)	1 (100%)	1 (100%)				
403*	M	4	6 (29%)	1 (25%)	1 (17%)	3 (75%)	5 (83%)		
404*	F	6	15 (56%)	6 (100%)	15 (100%)				
405*	F	4	7 (29%)	2 (50%)	3 (43%)	2 (50%)	4 (57%)		
406	M	7	8 (57%)	4 (57%)	5 (62%)	3 (43%)	3 (38%)		
407	M	2	3 (50%)			2 (100%)	3 (100%)		
408	F	2	4 (57%)			1 (50%)	3 (75%)	1 (50%)	1 (25%)
409	F	2	3 (100%)	1 (50%)	1 (33%)	1 (50%)	2 (67%)		
410	F	3	3 (75%)	3 (100%)	3 (100%)				
411	M	3	3 (75%)	3 (100%)	3 (100%)				
502	F	3	4 (33%)			3 (100%)	4 (100%)		

[A]Proportions are relative to total number of observations for each tortoise.
[B]Proportions are relative to total number of observations in burrows for each tortoise.
[C]Unmarked burrow.

Patterns of burrow use relative to vegetation type help explain discrepancies in relative habitat use as measured by home range area and frequency of observations within each vegetation type. For example, we found tortoises #400, 404, 410, and 411 in xeroriparian areas disproportionately more often than suggested by the relative amount of washes running through their home range polygons (Table 2). Amount of time spent in xeroriparian areas is a reflection of the number of xeroriparian burrows (caliche caves) used by these tortoises. All of the permanent burrows used by tortoises #404, 410, and 411, and 2/3 of those used by tortoise #400, occurred in xeroriparian areas (Table 4).

DISCUSSION

HOME RANGE AREAS

Observed home range areas in this study generally fell within ranges observed at other populations in the Sonoran (Averill-Murray and Klug 2000; Bailey 1992; Barrett 1990; Martin 1995; Murray and others 1995; Trachy and Dickinson 1993) and Mojave deserts (Burge 1977; Duda and others 1999; O'Connor and others 1994). However, estimates from this study are probably biased low, possibly due to the dry environmental conditions (Duda and others 1999) but surely also due to small sample sizes. Minimum convex polygon home range estimates increase as the number of locations increases (Jennrich and Turner 1969). Rautenstrauch and Holt (1995) found that the MCP method performed well with $\geq$60 locations per individual.

One recognized problem with the MCP method is the inclusion of area not actually used by the individual animal (White and Garrott 1990), a problem that can be exacerbated by moderately small sample sizes. For example, it is not evident whether male #403 used much, if any, of the eastern portion of his home range polygon (Fig. 2). Desert tortoise movement patterns at other sites consist of a period of time spent around a burrow or group of burrows before moving to another area, thus resulting in multiple, sometimes distant, centers of activity (O'Connor and others 1994; Rautenstrauch and Holt 1995). Most tortoises in the current study were not observed long enough to establish additional centers of activity. If animal locations are distrubuted uniformly throughout the home range area, the MCP method works well with adequate sample sizes (Rautenstrauch and Holt 1995).

HABITAT AND BURROW USE

Training Area B, the focal area of interest on FMR for this study, is characterized by gently sloping to flat alluvial slopes. This area is dominated by the bursage and paloverde/mixed cacti series and xeroriparian scrub (Fig. 1). The creosotebush and cholla series are also present, but shifts between all of these series are subtle (Snetsinger and Spicer 2001). More biologically relevant comparisons might be made simply between xeroriparian and combined upland habitats as additional data are collected at FMR.

Most of our initial tortoise captures occurred within xeroriparian areas as a result of our focus on searching caliche caves, and in fact most of the tortoises we tracked for at least a month spent a substantial amount of time in washes (Table 2). We initially expected to find tortoises using relatively linear home ranges along xeroriparian areas as they moved between caliche caves. Somewhat surprisingly, due to the fact that Sonoran tortoises do not typically inhabit valley floors outside of washes (Germano and others 1994), we also found telemetered tortoises spending substantial time within bursage-dominated habitat (Table 2). Home ranges for tortoises with >20 obervations did not follow linear wash courses, but most were centered around one or more washes (Figs. 2-3). Additional data are needed to investigate variable patterns we observed in habitat use relative to availability.

The paucity of observations of tortoises within firing boxes is an artifact of the fact that we found most tortoises south of the southern-most firing box. Several of these tortoises were found opportunistically while tracking individuals that had already been fitted with radio transmitters. Finding new tortoises was extremely difficult during 2000, especially given the types of shelters used by tortoises at FMR and limited tortoise activity due to the dry weather conditions. Many caliche caves are too deep to see tortoises that may be in the rear of the shelter, and it is virtually impossible to find untelemetered tortoises below individual plants in a sea of bursage.

Relative to other Sonoran Desert populations, burrow use at FMR is similar to that of tortoises in the San Pedro Valley (SPV) population, which also lacks large rocks and boulders under which tortoises could excavate (Bailey 1992; Woodman and others 1996). Most SPV burrows were in terrace gravel (54%) or diatomaceous earth (25%) (Woodman and others 1996). Terrace gravel burrows consisted of a cemented conglomerate of gravel and cobble near the top of steep slopes; these burrows formed deep caves where a terrace gravel layer met the coluvium on the slope. Burrows in diatomaceous earth were also located at the base of cliffs but closer to the base of slopes than terrace gravel burrows. The remaining burrows were found in other soil types (16%) or below rocks (4%). Caliche caves inhabited by tortoises at FMR were found at all levels of incised washes up to nearly 10 m in height.

A recent study at Fort Irwin in the central Mojave Desert of California found that males and females selected different types of shelters; adult females were found more often in soil burrows, and males were found more often in natural caves (Berry and others 2000). Furthermore, female burrow use differed by season, possibly as a result of nest-site selection. Juvenile tortoises were found primarily in soil burrows and rock shelters at this site. Finally, this study found that soil burrows and pallets were more vulnerable to collapse from natural and anthropogenic causes than were natural caves. During the study, zero of 85 natural caves or 22 rock shelters collapsed, while 30% of burrows collapsed or were damaged.

CONCLUSIONS

The observed use of primarily xeroriparian and bursage vegetation by desert tortoises is important relative to National Guard training activities because of the preponderance of bursage within all firing boxes (Fig. 1). Most firing boxes also include several kilometers of xeroriparian habitat, but we don’t yet know whether tortoise use of xeroriparian areas is exclusively tied to the presence of caliche caves. In fact, we don’t yet know whether tortoise distribution across FMR is clustered around particular habitat features such as caliche caves or if tortoises are more or less uniformly distributed at low density. For example, was tortoise use of bursage habitat tied to some maximum distance from a caliche cave? The high proportion (48%) of burrows in nonxeroriparian habitats also suggests that tortoises in those burrows may be at increased risk of injury from training activities or other off-road vehicle recreation (Berry and others 2000).

As illustrated by Figures 2-3, additional study (including monitoring additional radio-marked tortoises north of firing box #700) would allow precise estimates of proportional habitat use, especially relative to firing boxes. Applying methods of compositional analysis to a larger set of habitat use data would allow analysis at 2 scales: 1) home range selection within the overall study area and 2) habitat use within individual home ranges (Aebischer and others 1993). Finally, other potential sources of variation in tortoise habitat use should not be overlooked. Do adult males and females select different habitats, particularly relative to female egg-laying (e.g., Berry and others 2000)? Do juvenile tortoises select different habitats? How does habitat use change relative to different environmental conditions (*cf.* Duda and others 1999)?

This pilot study demonstrated the potential information that additional research can provide to understand tortoise habitat use at FMR. This information will be valuable for making meaningful management recommendations regarding National Guard training activities, especially relative to firing boxes, and possibly regarding recreational off-road uses in the area.

Recommendations

*Conduct additional surveys for tortoises throughout Training Area B for a minimum of 2 additional years. Map all tortoise locations and all caliche caves.

*Continue monitoring telemetered tortoises for a minimum of 2 additional years, bringing the total number of adult telemetered tortoises up to at least 14 with an approximately equal sex ratio. Radio-mark 5 juvenile desert tortoises, as available. Focus on adding telemetered tortoises north of firing box #700. Monitor telemetered tortoises approximately 3 days per week during the active season (March-October) and 1 day per week during the inactive season (November-February).

*Radiograph females during the reproductive season and determine nesting locations.

*Evaluate the utility of home range estimators that allow multiple activity centers, including cluster methods and kernel analyses (Hooge and Eichenlaub 1997; Kenward and Hodder 1996), relative to the minimum convex polygon method.

*Conduct a compositional analysis of habitat use and home ranges (Aebischer and others 1993) based on the evaluation of home range methods. Relate results from this analysis to firing boxes.

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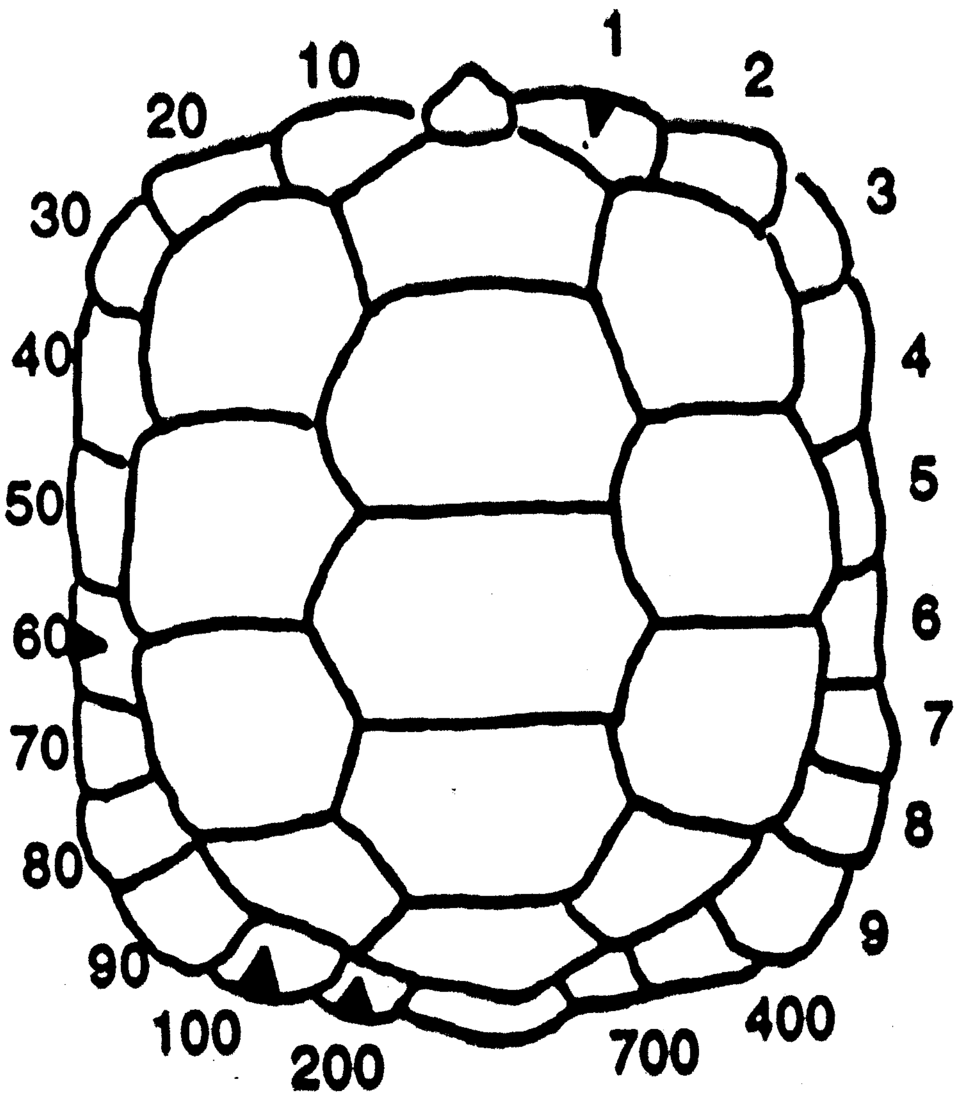
APPENDIX: TORTOISE MARKING SYSTEM



Tortoise number = 361